WRF Four-Dimensional Data Assimilation (FDDA)

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ARW only

FDDA

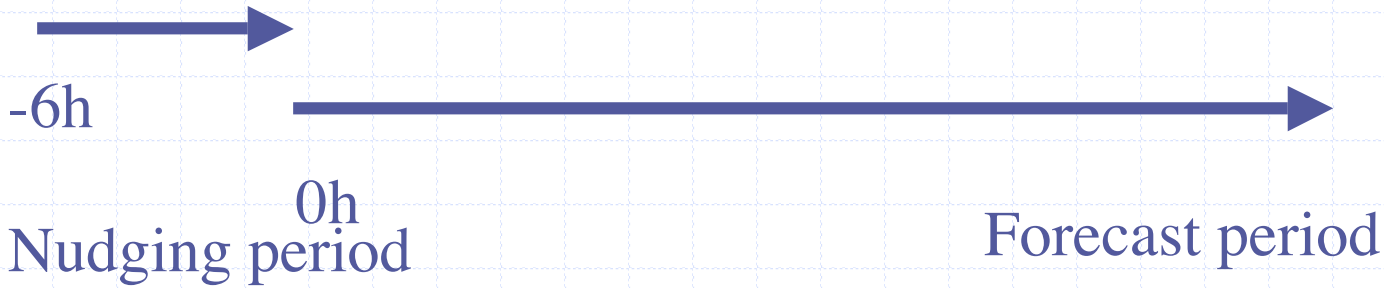
- Method of nudging model towards observations or analysis
- May be used for
  - Dynamical initialization (pre-forecast period)
  - Creating 4D meteorological datasets (e.g. for air quality model)
  - Boundary conditions (outer domain nudged towards analysis)

Method

- Model is run with extra nudging terms for horizontal winds, temperature and water vapor
- In analysis nudging, these terms nudge point-by-point to a 3d space- and time-interpolated analysis field
- In obs-nudging, points near observations are nudged based on model error at obs site
- The nudging is a relaxation term with a user-defined time scale around an hour or more
- Nudging will work with nesting and restarts

Dynamic Initialization

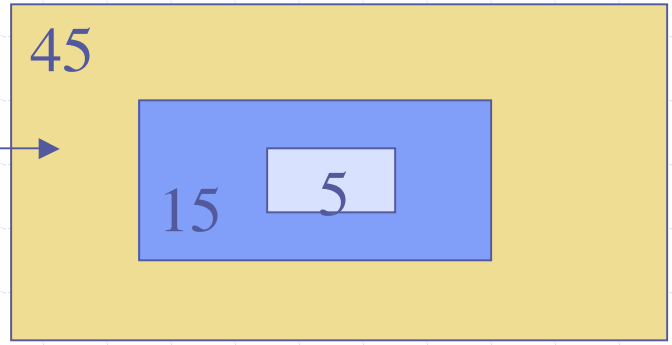
- Model domains are nudged towards analysis in a pre-forecast period of 6-12 hours
- This has benefit of smooth start up at forecast time zero



Boundary Conditions

- Nudge an outer domain towards analysis through forecast
- This has benefit of providing smoother boundary conditions to domain of interest than if 15 km domain is the outer domain with interpolated-analysis boundary conditions

Nudge 45 km domain only



FDDA Methods

- Two Methods
  - Grid or analysis nudging (suitable for coarse resolution)
  - Observation or station nudging (suitable for fine-scale or asynoptic obs)
- Nudging can be applied to winds, temperature, and water vapor

Note: nudging terms are fake sources, so avoid FDDA use in dynamics or budget studies

Analysis Nudging (grid_fdda=1)

- Each grid-point is nudged towards a value that is time-interpolated from analyses

$$\frac{\partial p^* \alpha}{\partial t} = F(\alpha, \mathbf{x}, t) + G_\alpha \cdot W_\alpha \cdot \epsilon_\alpha(\mathbf{x}) \cdot p^*(\hat{\alpha}_0 - \alpha)$$

In WRF p* is mu

Analysis Nudging

$$\frac{\partial p^* \alpha}{\partial t} = F(\alpha, \mathbf{x}, t) + G_\alpha \cdot W_\alpha \cdot \epsilon_\alpha(\mathbf{x}) \cdot p^*(\hat{\alpha}_0 - \alpha)$$

- G is nudging inverse time scale
- W is vertical weight (upper air and surface)
- ε is a horizontal weight for obs density (not implemented yet)

Analysis Nudging

- 3d analysis nudging uses the WRF input fields at multiple times that are put in wrffdda file by program real when run with grid_fdda=1
  - With low time-resolution analyses, it is recommended not to use 3d grid-nudging in the boundary layer, especially for temperature
- Surface (2d) analysis nudging not available yet (maybe later after Version 3)

Analysis-Nudging namelist options

Can choose

- Frequency of nudging calculations (fgdt in minutes)
- Nudging time scale for each variable (guv, gt, gq in inverse seconds)
- Which variables not to nudge in the PBL (if_no_pbl_nudging_uv, etc.)
- Model level for each variable below which nudging is turned off (if_zfac_uv, k_zfac_uv, etc.)
- Ramping period over which nudging is turned off gradually (if_ramping, dt_ramp_min)

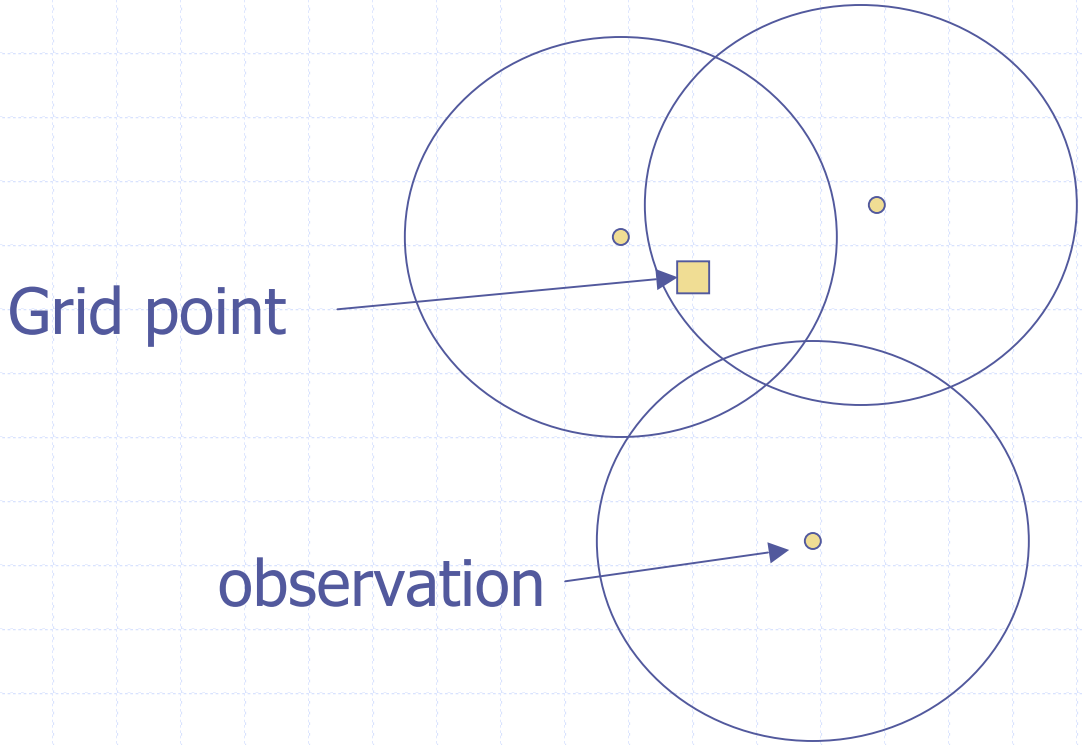
Obs Nudging (obs_nudge_opt=1)

- Each grid point is nudged using a weighted average of differences from observations within a radius of influence and time window

$$\frac{\partial p^* \alpha}{\partial t} = F(\alpha, \mathbf{x}, t) + G_\alpha \cdot p^* \frac{\sum_{i=1}^{N} W_i^2(\mathbf{x}, t) \cdot \gamma_i \cdot (\alpha_o - \hat{\alpha})_i}{\sum_{i=1}^{N} W_i(\mathbf{x}, t)}$$

$$W(\mathbf{x}, t) = w_{xy} \cdot w_\sigma \cdot w_t$$

Obs Nudging



Obs Nudging

$$w_{xy} = \frac{R^2 - D^2}{R^2 + D^2} \qquad 0 \leq D \leq R$$

$$w_{xy} = 0 \qquad D > R,$$

- R is radius of influence
- D is distance from ob modified by elevation difference

Obs Nudging

$$w_t = 1 \qquad |t - t_0| < \tau/2$$

$$w_t = \frac{\tau - |t - t_0|}{\tau/2} \qquad \tau/2 \leq |t - t_0| \leq \tau$$

- τ is the specified time window for the obs
- This is a function that ramps up and down

Obs Nudging

- w_σ is the vertical weighting – usually the vertical influence is set small (0.005 sigma) so that data is only assimilated on its own sigma level
- obs input file is a special ascii file with obs sorted in chronological order
    - each record is the obs (u, v, T, Q) at a given model position and time

Obs-Nudging namelist options

Can choose

- Frequency of nudging calculations (iobs_ionf)
- Nudging time scale for each variable (obs_coef_wind, etc.)
- Horizontal and vertical radius of influence (obs_rinxy, obs_rinsig)
- Time window (obs_twindo)
- Ramping period over which nudging is turned off gradually (obs_idynin, obs_dtramp)

FDDA Summary

- FDDA grid nudging is suitable for coarser grid sizes where analysis can be better than model-produced fields
- Obs nudging can be used to assimilate asynoptic or high-frequency observations
- Grid and obs nudging can be combined
- FDDA has fake sources and sinks and so should not be used on the domain of interest and in the time period of interest for scientific studies and simulations

Further plans

- Add 2d (surface) nudging and integrate with 3d nudging
- Integrate with analyses produced by WRF-Var

End